Current Transformer Standards

Current Transformer Specification

Inquiry Check list to order a CT

- Applicable standards
- Rated frequency
- Highest system voltage
- Test voltage (power frequency, lightning impulse)
- Primary / secondary rated currents
- Short time current and duration
- Environmental conditions (altitude, temperatures, pollution, seismic conditions…)

Current Transformer Standards

List of the main standards

- IEC 185 / New : IEC 60044-1
- British standard BS 3938
- IEC 60044-6 : Transient performances
- ANSI Standards
- Non conventional Instrument transformer :
  IEC 60044-8
  IEC 61850-9-1

Current Transformer Specification
IEC 185 - IEC 44-1

Specified in terms of :

i) Rated transformation ratio (Kn = Ipn / Isn)
Standard rated primary current :
10, 12.5, 15, 20, 25, 30, 40, 50, 60, 75 and their decimal multiples or fraction.
Standard rated secondary current :
1A, 2A or 5A

ii) Accuracy Class :
5P or 10P

iii) Accuracy Limit Factor :
Standard Value : 5, 10, 15, 20, 30

iv) Output power :
Standard value : 2.5, 5, 10, 15 and 30VA

Exemple : 800/1A 5P20 15VA

Current Transformer Specification
IEC 185 - IEC 44-1

Error definitions :

i) Current error (ratio error) :

Current error (%) $= \dfrac{(Kn \cdot Is - Ip) \times 100}{Ip}$

Actual transformer ratio is not equal to rated transformer ratio due to turn correction.

ii) Composite error :

$$\varepsilon_c = \frac{100}{Ip} \cdot \sqrt{\frac{1}{T} \cdot \int_0^T (Kn.is - ip)^2 . dt}$$

Kn = rated transformer ratio
Ip = r.m.s value of the primary current
ip = instantaneous value of the primary current
is = instantaneous value of the secondary current
T = duration of one cycle

Current Transformer Specification IEC 185 - IEC 44-1

Limits of error

Accuracy Class	Current Error at rated primary current (%)	Phase Displacement at rated primary current		Composite Error (%) at rated accuracy limit primary current
		Minutes	Centiradians	
5P	±1	±60	±1.8	5
10P	±3			10

Remember : all the data are available only for symmetrical AC current

Current Transformer Specification BS 3938

Class “X”

Specified in terms of :-

i) Rated Primary Current

ii) Turns Ratio (max. error = 0.25%)

iii) Knee Point Voltage

iv) Mag Current (at specified voltage)

v) Secondary Resistance (at 75°C)

Current Transformer Specification BS 3938

Classes :- 5P, 10P. 'X'

Designation (Classes 5P, 10P)

(Rated VA) (Class) (ALF)

Multiple of rated current (I_N) up to which declared accuracy will be maintained with rated burden connected.

5P or 10P.

Value of burden in VA on which accuracy claims are based.
(Preferred values :- 2.5, 5, 7.5, 10, 15, 30 VA)

Z_B = rated burden in ohms
= Rated VA/ I_N^2

Current Transformer Specification IEC 44-6

Specified in terms of :

i) Rated transformation ratio (Kn = Ipn / Isn)
Standard rated primary current :
10, 12.5, 15, 20, 25, 30, 40, 50, 60, 75 and their decimal multiples or fraction.
Standard rated secondary current :
1A, 2A or 5A

ii) Rated symmetrical short-circuit current factor (Kscc = Ipsc / Ipn)
Standard value : 3, 5, 7.5, 10, 12.5, 15, 17.5, 20, 25, 30, 40, 50

iii) Rated transient dimensioning factor (Ktd) :

iv) Specified primary time constant (Tp) :
Standard value in msec: 40, 60, 80, 100, 120

Current Transformer Specification IEC 44-6

Specified in terms of :

v) Rated secondary loop time constant (Ts = Ls / Rs) :
Ls = leakage inductance
Rs = Total resistance of the secondary circuit (including Rct)

vi) Duty cycle :
Single energization : C - t' - O :
Double energization : C - t' - O - t_{fr}- C - t" - O
t' = duration of the first current flow
t'al = specified accuracy is maintained during this time
t" = duration of the second current flow
t"al = specified accuracy is maintained during this time
tfr = dead time during auto-reclosing

vii) Rated resistive burden (Rb) :
Standard for 1A : 2.5, 5, 7.5, 10, 15 in ohms

Current Transformer Specification
IEC 44-6

Error definitions :

i) Peak instantaneous (total) error :
Accuracy on both AC & DC components

$$\hat{\varepsilon} = 100 \cdot \hat{i}_{\varepsilon} / \left(\sqrt{2} \cdot Ipsc \right)$$

ii) Peak instantaneous alternating current component error :
Accuracy on AC component

$$\hat{\varepsilon}_{ac} = 100 \cdot \hat{i}_{\varepsilon ac} / \left(\sqrt{2} \cdot Ipsc \right)$$

Current Transformer Specification IEC 44-6

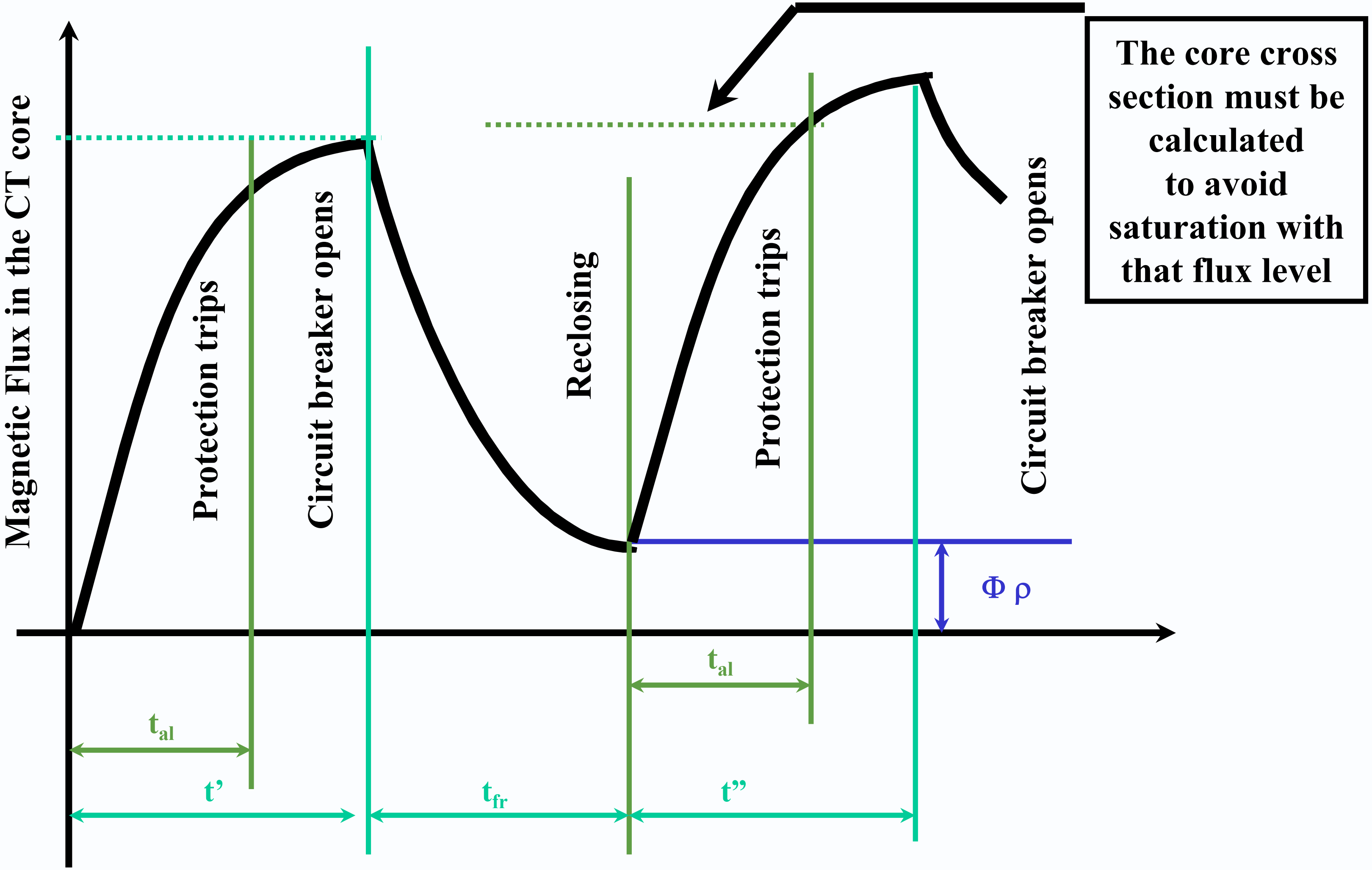
Limits of error

Class	Ratio error (%) at primary rated current	Phase Displacement at rated primary current		Maximum peak instanteneous value error (%) at rated accuracy limit condition
		Minutes	Centiradians	
TPX	± 0.5	± 30	± 0.9	$\varepsilon = 10$
TPY	± 1.0	± 60	± 1.8	$\varepsilon = 10$
TPZ	± 1.0	180 ± 18	5.3 ± 0.6	$\varepsilon_{ac} = 10$

Class TPS = class X of BS

Current Transformer Specification IEC 44-6

Duty cycle : C - t' - O - t_{fr} - C - t" - O



Current Transformer Specification IEC 44-6

Transient dimensioning factor equations :

Transient factor for a fully offset short-circuit current after t seconds :

$$Ktf(t) = 1 + [w*Tp*Ts / (Tp-Ts)] * [\exp(-t/Tp) - \exp(-t/Ts)]$$

Ktf will have a maximum value at tmax :

$$tmax = [Tp*Ts / (Tp-Ts)] * \ln (Tp/Ts)$$

For a C-O cycle (without Auto-Reclosing) :

The accuraccy must be maintained during the time t 'al

If t 'al < tmax then :

Ktd = Ktf(t 'al)

If t 'al > tmax then :

Ktd = Ktfmax

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Current Transformer Specification IEC 44-6

Transient dimensioning factor equation :

For a C-O-C-O cycle (with Auto-Reclosing) :

The Ktd is the sum of two terms :

$$Ktd = Ktd1 + Ktd2$$

$$Ktd1 = Ktf(t') * \exp[-(tfr+t''al) / Ts]$$

$$Ktd2 = Ktf(t'')$$

Calculation of the Knee voltage :

$$Eal = Ktd.Kscc.Ins.(Rct + Rb)$$

Current Transformer Specification IEC 44-6

Method of specification :

CT class	TPS	TPX	TPY	TPZ
Rated primary current	x	x	x	x
Rated secondary current	x	x	x	x
Rated Frequency	x	x	x	x
Highest voltage for equipment and rated insulation level	x	x	x	x
Ith	x	x	x	x
Idyn	x	x	x	x
Ratio	x	x	x	x
Kssc	x	x	x	x
Tp	-	x	x	x
Ts	-	-	-	-
Duty cycle Single : t' ; t'al Double : t' ; t'al ; ttr ; t" , t"al	-	x	x	-
Rb	x	x	x	x
K	x	-	-	-
Maximum Ial at Ual	x	-	-	-
Rct	x	-	-	-

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Current Transformer Specification IEC 44-6

Information to be included in the rating plate :

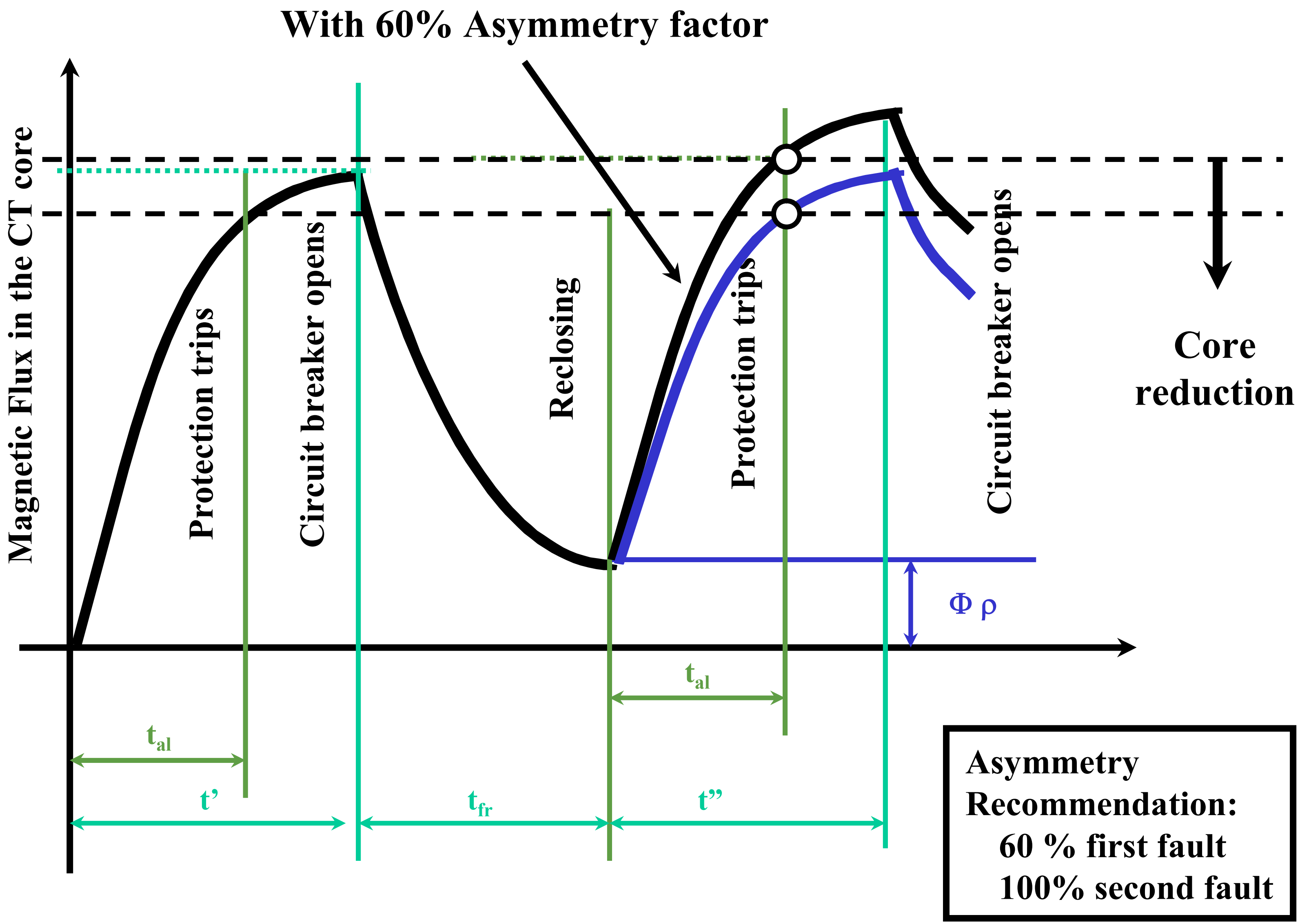
CT class	TPS	TPX	TPY	TPZ
Ipn	x	x	x	x
Isn	x	x	x	x
Ith	x	x	x	x
Idyn	x	x	x	x
Kssc	x	x	x	x
Rb	x	x	x	x
Rct (at …°C)	x	x	x	x
Ktd	-	x	x	x
K	x	-	-	-
Ual	x	x	x	x
Ial	-	x	x	x
Fc	-	x	x	x
Tp	-	x	x	x
Ts	-	-	x	-
Duty cycle Single : t' ; t'al Double : t' ; t'al ; ttr ; t" , t"al	-	x	x	-

Current Transformer Specification IEC 44-6
Influence of the asymetry factor

- Asymmetry factor
  - Failure occurs when we have minimum 40% of the rated voltage; the resulting short circuit current will be displaced of 60% (Asymmetry coef=0.6).
  - Asymmetry of 100% is only possible with a direct lightning stroke on the HV conductor, what is very unlikely if the overhead line is protected with a ground wire.
  - After reclosing, if we have a permanent fault, it is likely to have the short circuit current when de voltage is zero; it is more likely to have an asymmetry factor of 100% after the reclosing operation
  - Many utilities specify
    - 60 % asymmetry for the first fault
    - 100% asymmetry for the second fault (after reclosing)

Current Transformer Specification IEC 44-6

Influence of the asymmetry factor



Choice of Current Transformer

i) Instantaneous Overcurrent Relays
- Class P Specification
- A.L.F. = 5 usually sufficient
- For high settings (5 - 15 times C.T rating)
  A.L.F. = relay setting

ii) IDMT Overcurrent Relays
- Generally Class 10P
- Class 5P where grading is critical

iii) Differential Protection
- Class X Specification
- Protection relies on balanced C.T output

Non Conventional CT`s

Non Conventional CT's

Two methods are commonly referred to:

- Rogowski Coils
- Optical CT`s

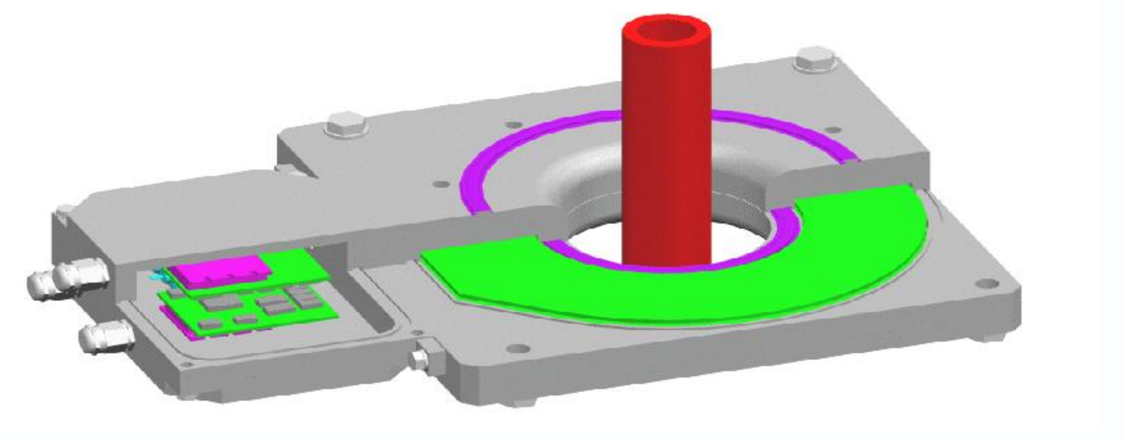
Rogowski Coils

- Invented 1912
- Described as a poorly coupled transformer
- No magnetic circuit
- Can be flexible or solid construction
- Core only used to support secondary coil

Rogowski Coils : principle

Output signal is a voltage proportional to the derivative of the primary current

$$\boxed{Vs = S \cdot \frac{\partial i_p}{\partial t} \cdot \frac{R}{R + r}}$$



With following definitions:

Ip: **Primary current**
Is: **Secondary current**
Vs: **Secondary voltage**
S: **Sensitivity of Rogowski sensor**
r: **Serial resistance**
R: **Secondary load**

Rogowski Coils - Advantages

- No Saturation
- No Remenance
- Reduced Distortion - Since no inductance

Rogowski Coils - Disadvantages

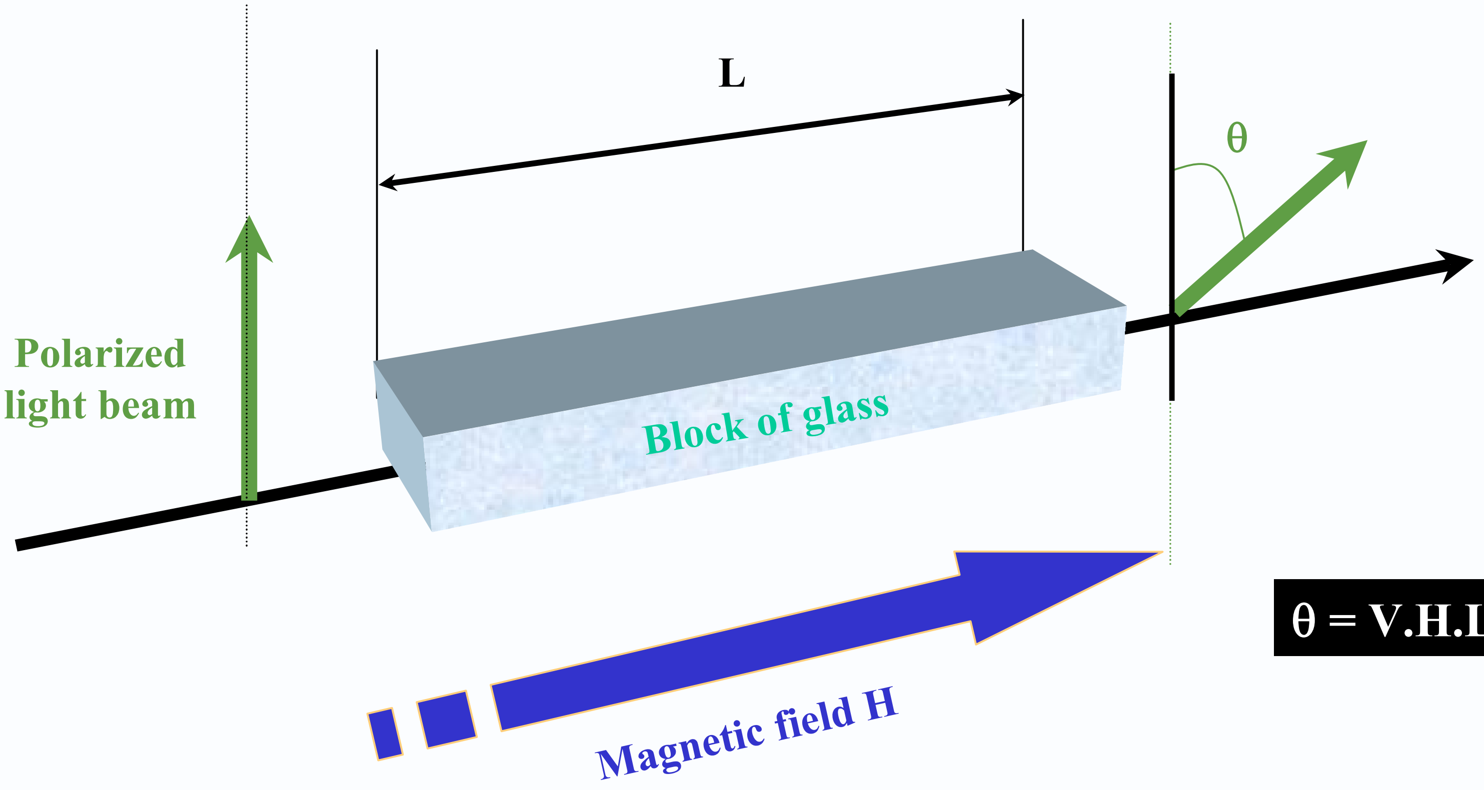
- Small Output - not problem with modern relays
- Differentiates input, therefore requires integration
- Harmonics are amplified
- Susceptible to noise

Optical CT`s

- First used for high voltage current measurement in the late 1960`s
- Various constructions - typically optical fibre wrapped around the conductor
- Detects rotation of the plane of polarisation of linearly polarised light in proportion to a magnetic field through the material

Optical CT`s : principle

Faraday effect

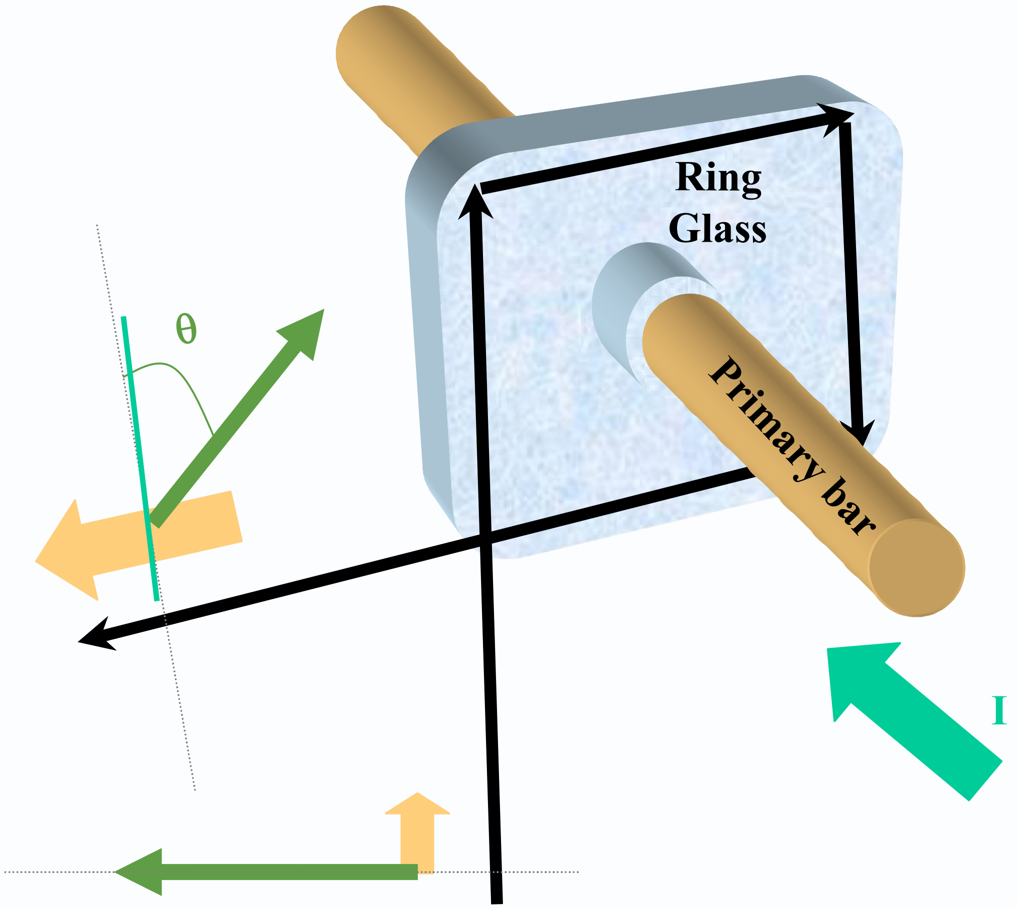


$\theta = V.H.L$

V: Verdet constant

Optical CT`s : principle

AMPERE theorem

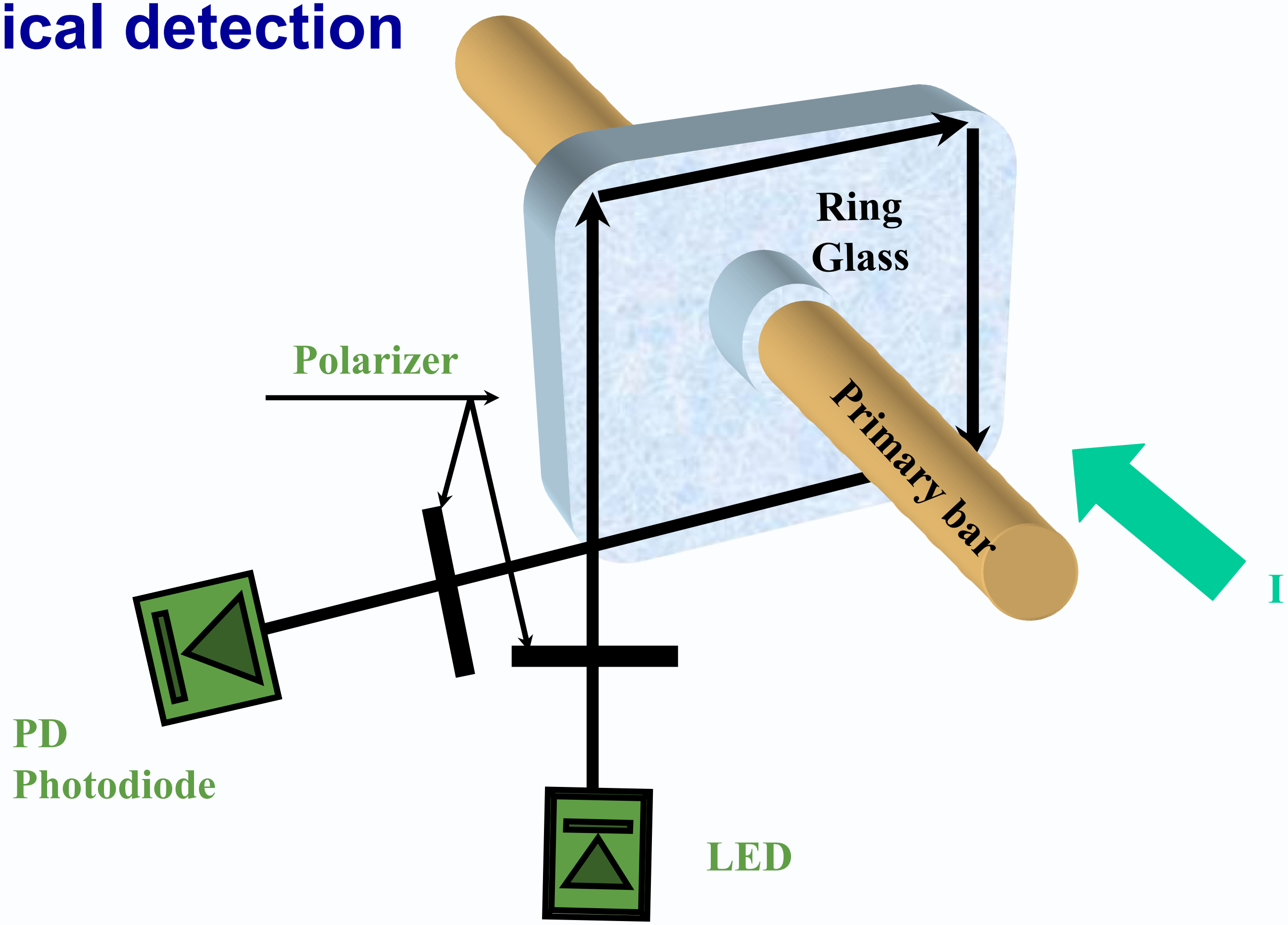


$$\oint \vec{H}.dL = I$$

$$\theta = V.I$$

Optical CT`s : principle

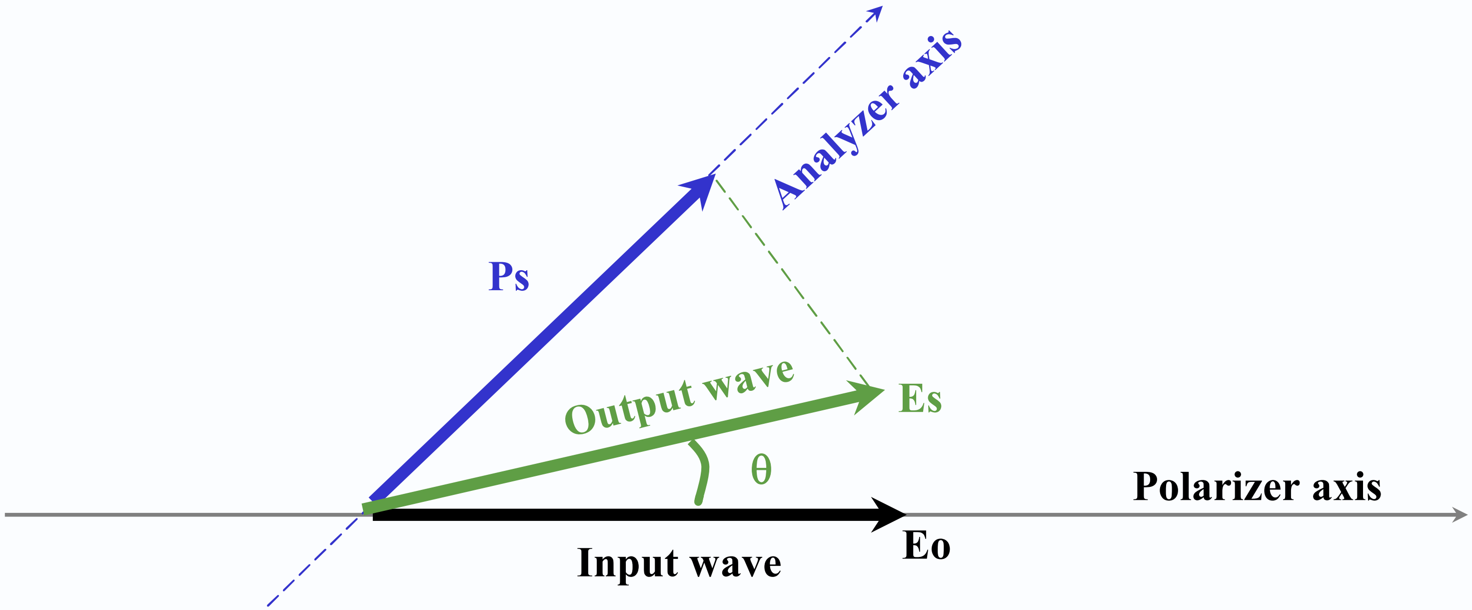
Optical detection



Polarization rotation becomes Light intensity modulation by addition of a "polarimetric system"

Optical CT`s : principle

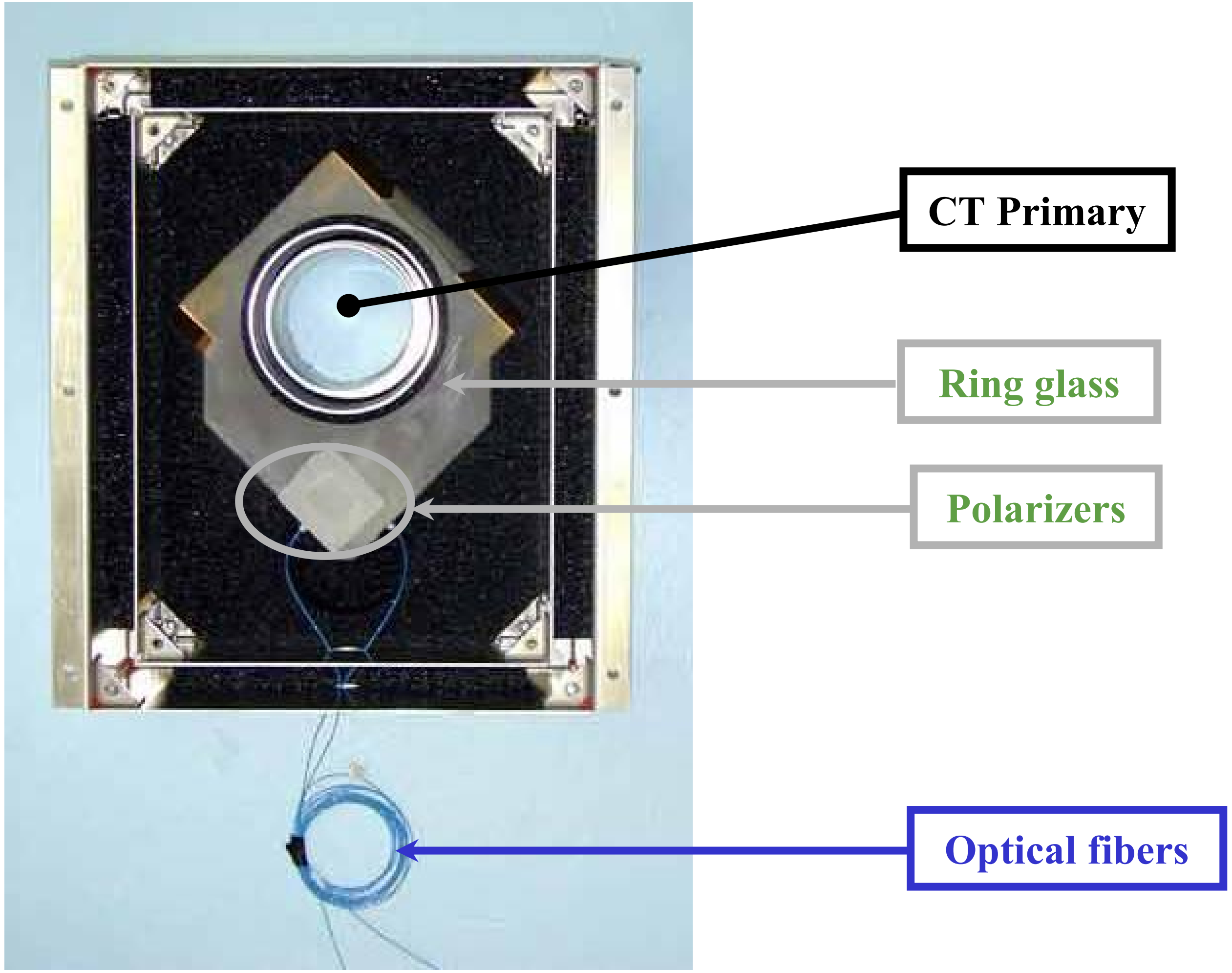
Electronic Signal Processing



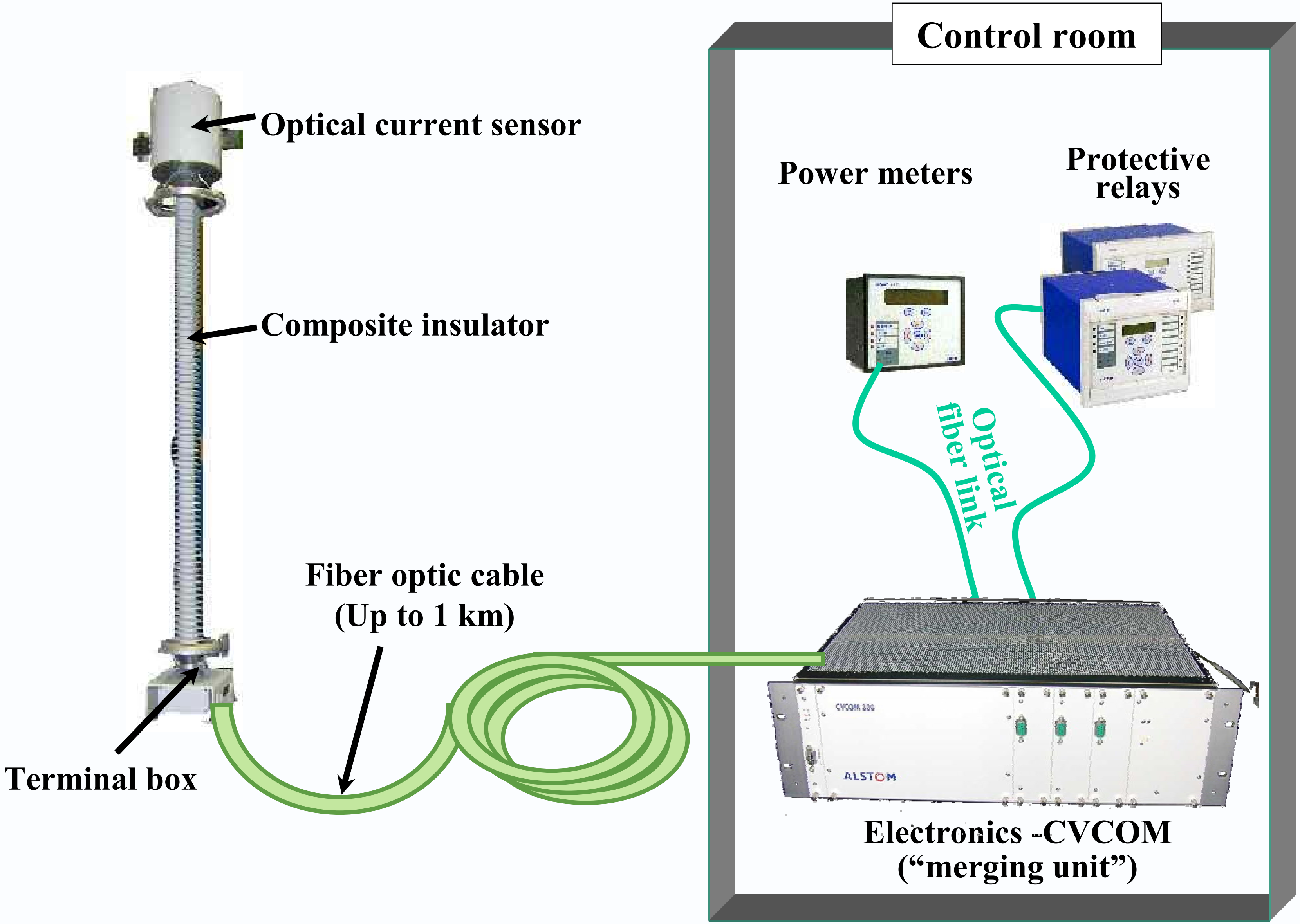
$$P_S = \frac{P_0}{2}(1 + \sin 2\theta)$$

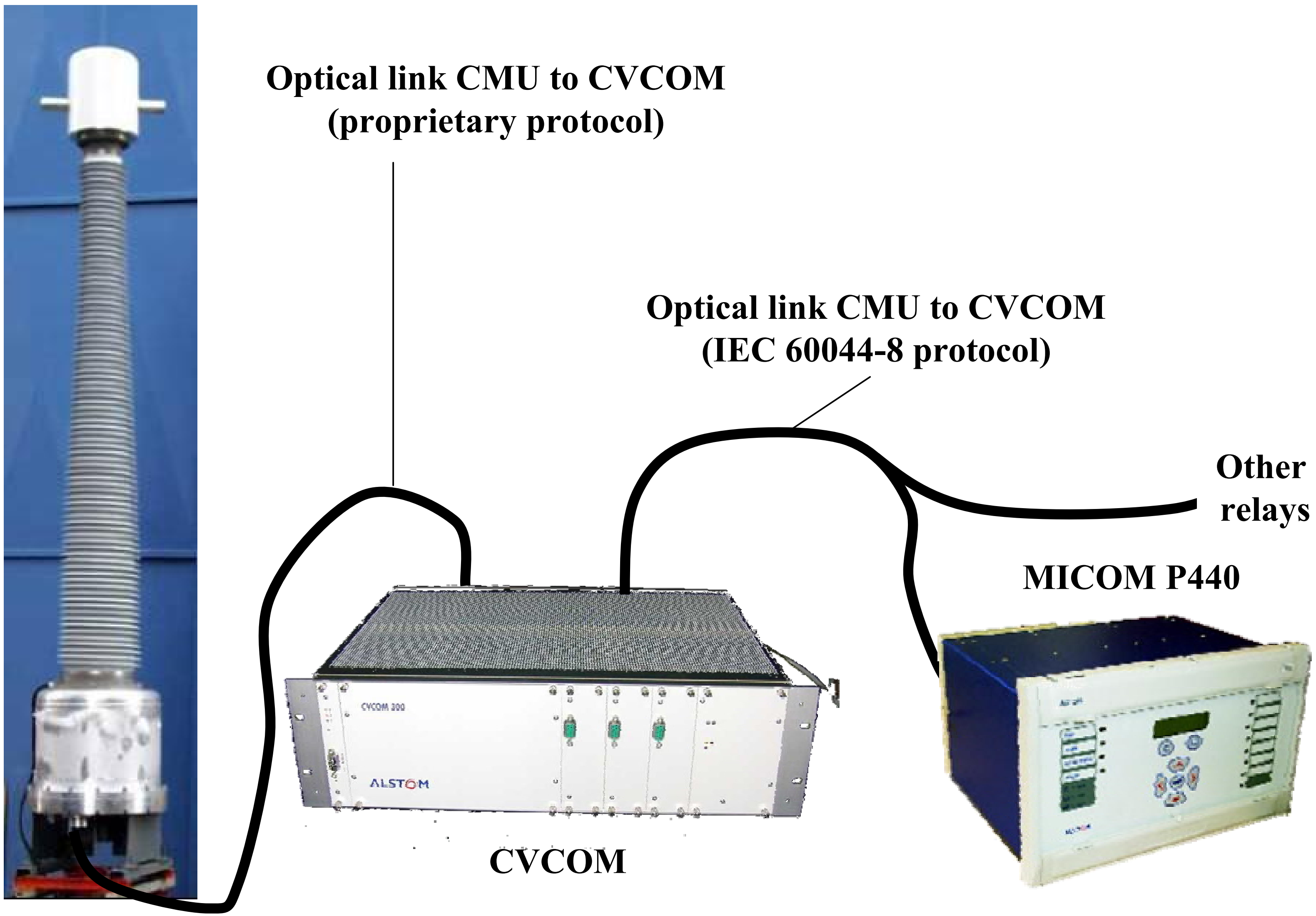
$$\boxed{\theta = V.I}$$

CT Head
Faraday Sensor



Optical CT in a Substation




Optical link CMU to CVCOM
(proprietary protocol)
Optical link CMU to CVCOM
(IEC 60044-8 protocol)
Other
relays
MICOM P440
CVCOM 200
ALSTOM
CVCOM

Optical CT`s - Advantages

- Light Weight
- Smaller support structure
- Noise Immunity
- Safe
- No Saturation

Optical CT`s - Disadvantages

- Detectors can be expensive
- Affected by changes in Temperature and Pressure - need to account for this in detector
- Delicate
- Only used on EHV